# THE ILLINOIS SIGNAL PROCESSING CURRICULUM: PAST, PRESENT, AND FUTURE

*David C. Munson, Jr. and Andrew C. Singer*

Dept. of Electrical and Computer Engineering
and Coordinated Science Laboratory
University of Illinois at Urbana–Champaign
Urbana, IL 61801 USA
{d-munson,acsinger}@uiuc.edu

**ABSTRACT**

This paper describes the undergraduate and graduate signal processing curriculum at the University of Illinois. This curriculum has been developed over a period of about 25 years. It is taught largely by a group of eleven faculty and it serves to educate hundreds of students per semester for both industrial practice and cutting-edge research.

## 1. HISTORY

At most universities, activities in signal processing were originated by faculty in one of three established fields: communications, control systems, or circuits. At the University of Illinois, modern signal processing was launched within the circuits group by Professor Timothy Trick, who began regularly teaching a graduate-level course on digital signal processing (DSP) in the mid 1970s. Professor William Perkins, from the control systems area, soon followed with the introduction of an undergraduate course on the same topic. Professors W. Kenneth Jenkins, David Munson, and Thomas Huang were the first DSP faculty hired at Illinois, during the period 1977-1980. They worked to build both a curriculum and a graduate research program in signal and image processing. Their most important activity was to bring in many additional colleagues who were to become large contributors in their own right. These faculty were K.S. Arun, Yoram Bresler, Douglas Jones, Michael Orchard, Yunxin Zhao, Zhi-Pei Liang, Kannan Ramchandran, Pierre Moulin, Naresh Shanbhag, Richard Blahut, Steven Levinson, Andrew Singer, Mark Hasegawa-Johnson, Chris Hadjicostis, and Helmut Bolcskei. The Signal and Processing Group at the University of Illinois now numbers 11 faculty and approximately 100 graduate students. The curriculum and research interests of the group cover nearly all aspects of signal, image, and speech processing, including important application areas such as communications and medical imaging.

The purpose of this paper is to describe the Illinois "curriculum in signal processing." We emphasize, however, that there is no formal signal processing curriculum at Illinois. To some extent, faculty in communication, control, and signal processing share the teaching of courses throughout the general systems area. Few courses are thought of as belonging to a group of faculty or to any individual faculty member. For the purposes of this paper we shall consider the curriculum in signal processing to consist of all courses in analog and digital signal processing, including image processing and imaging systems, speech processing, and closely related subjects that draw large enrollments from "signal processing students." Section 2 describes the undergraduate curriculum. Section 3 discusses the graduate curriculum. In Section 4, we conclude with some comments on where the Illinois signal processing curriculum is headed in the future.

## 2. UNDERGRADUATE CURRICULUM

The courses in the undergraduate signal processing curriculum are listed in Table 1.

| Number | Course Title | hours |
|---|---|---|
| ECE 210 | Analog Signal Processing | 4 |
| ECE 310 | Digital Signal Processing | 4 |
| ECE 313 | Probability with Eng. Applications | 3 |
| ECE 320 | Digital Signal Processing Laboratory | 2 |
| ECE 318 | Intro to Image and Video Processing | 4 |
| ECE 371 | VLSI for Signal Processing | 3 |
| ECE 371 | Intro to Speech Processing | 3 |
| ECE 380 | Magnetic Resonance Imaging | 3 |

Table 1: Undergraduate Courses

The courses labeled ECE 371 are not yet permanent, although the plan is to make them such. Numerous related courses in communication and control are routinely taken by students having signal processing interests, and are not listed in Table 1.

The undergraduate signal processing curriculum begins with ECE 210, which is taken in the sophomore year. This required course introduces the fundamentals of circuit analysis and then quickly moves to op amps and the concept of filtering. Little time is spent on solution of differential equations. Instead, emphasis is placed on sinusoidal steady-state and frequency response, where the students see phasors, Fourier series, and the Fourier transform in succession. A detailed analysis of the AM superheterodyne radio serves as a vehicle for exploring numerous Fourier concepts. We

then introduce the Laplace transform, partly as a system analysis tool and partly to assist us in analog filter design. Students design, build, and characterize filters in the laboratory and also build an AM radio.

This early introduction to Fourier concepts lets us teach a rigorous course in DSP, ECE 310, to a mixture of juniors and seniors. This course is taught at the level of the text by Proakis and Manolakis, but we use course notes instead of a textbook. Indeed most of our signal processing courses are taught from notes developed by the faculty, rather than from textbooks. ECE 310 is primarily a theoretical course, but Matlab is taught to the students as part of the homework assignments. ECE 310 is on a list of five courses, from which students must elect at least three. The enrollment in ECE 310 ranges from 110 - 150 students per semester. ECE 310 is considered the entry-way to the remainder of the signal processing curriculum.

Among the other courses in Table 1, ECE 320 deserves special mention. This 2-hour laboratory course is based on the TI TMS 320 development system. After a few set labs, students in this course spend the majority of their time completing special projects. Many of the projects are in the communications and speech/audio areas. Instructors of ECE 320 report that this is the course where the "lights go on" and theoretical ideas from ECE 310 become reality. The enrollment in ECE 320 is 60 students per semester.

## 3. GRADUATE CURRICULUM

Table 2 lists the courses in the Illinois graduate signal processing curriculum.

| | |
|---|---|
| ECE 413 | Digital Signal and Spectral Analysis |
| ECE 434 | Random Processes |
| ECE 437 | Fundamentals of Speech Processing |
| ECE 447 | Image Processing |
| ECE 451 | Advanced Digital Signal Processing |
| ECE 458 | Digital Imaging |
| ECE 463 | Information Theory |
| ECE 497 | Wavelets in Signal Processing |
| ECE 497 | Linguistic Models in Speech Processing |
| ECE 497 | VLSI Design for Sig. Proc. and Commun. |
| ECE 497 | Pattern Recognition |
| ECE 497 | Neural Networks for Signal Processing |

Table 2: Graduate Courses

The courses labeled ECE 497 are not permanent, although the first three are likely to become so. Many related courses in communications, coding theory, control, optimization, and mathematics are not listed and are routinely taken by signal processing students. Our Ph.D. students typically take courses in linear algebra and real analysis. Some go on to complete graduate coursework in measure theory and measure theoretic probability.

ECE 451 is the primary entry-way to graduate study in all areas of signal processing. ECE 451 is a mix between the classic text by Oppenheim and Schafer and more advanced material. ECE 451 typically reviews sampling and discrete-time system theory and then goes on to cover advanced methods of digital filter design, multirate signal processing, quantization effects, adaptive filtering, and fast algorithms. This course is taught once per year, with an enrollment of 50-60.

ECE 413 is a treatment of signal processing from a Hilbert space perspective, based on linear algebra and least squares. Spectral estimation is a prime application area covered in this course. Although ECE 413 draws only a small enrollment, it covers modern material that is critical for Ph.D. study.

ECE 458 treats many imaging systems in a unified way, from a signal processing perspective. Topics include 2-D Fourier transforms, projection-slice theorems, ambiguity functions, range-Doppler radar, synthetic aperture radar, tomography, Fourier optics, radio astronomy, and array processing.

## 4. THE FUTURE CURRICULUM

There are two factors that are likely to shape the Illinois curriculum in the future. First, the faculty will continue to create new courses in response to research trends and industrial needs. We are especially hard at work planning our curriculum in the speech processing area. To simplify the procedure for integrating newer courses into our curriculum, we are planning to initiate a Topics in Signal Processing course where the topic will vary from semester to semester. This will enable us to teach newer or specialized subjects on a rotating basis without obtaining departmental authorization for each offering.

A second factor concerns off-campus education. The ECE Department at Illinois has had an off-campus M.S. degree for many years. The enrollment has been low, however, partly due to technological limitations and partly because we have required (until now) an M.S. thesis. Last year, the faculty voted to make the M.S. thesis optional, and this year the university is moving heavily into web-based off-campus education. This trend will affect the teaching activities of our faculty, and perhaps our curriculum, in ways that are yet to be determined.